# RELATIONSHIP BETWEEN PRECIPITATION IN VALLEYS AND ON ADJOINING MOUNTAINS IN NORTHERN UTAH [1]

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*Synopsis.*—It is well known that precipitation varies widely within short distances, particularly where physical features are different. It is also well known that precipitation varies widely with elevation. Due to inaccessibility of high mountain areas few records are available to indicate the relationship of valley to mountain precipitation. In an arid region the high mountains are the source of the stream flow supplying agricultural, industrial, and municipal uses. This paper deals with variation in precipitation at different points on the valley floor and also compares the amount and distribution of precipitation on the valley floor with that above 8,000 feet.

## INTRODUCTION

The development and growth of a community in an arid or semiarid region is measured by the amount and distribution of its water supply. Agriculture is dependent upon the artificial application of water for the production of crops. Communities are dependent upon water for their growth and industrial development. Hydroelectric power generation is also dependent upon the flow of streams.

The major source of waters flowing in the streams in an arid region is in the high mountains adjacent to the valleys. For many years precipitation records have been kept at valley stations. Due to the inaccessibility of the high watersheds in the winter, to the scarcity of permanent inhabitants, and to the difficulty of measuring precipitation which falls as snow, few records or precipitation are available at high elevations.

There were some 91 cooperative weather bureau stations reporting precipitation in Utah at the end of 1930. Of these 91, only 7 were at 7,000 feet elevation or above. Of the 84 below 7,000 feet elevation, 37 were below 5,000 feet elevation and 72 were below 6,000 feet elevation. In addition to the above regular cooperative stations there were 10 or 15 high elevation stations reporting only summer precipitation. Snow stakes and snow surveys furnished some data on precipitation above 8,000 feet elevation.

It has been estimated that approximately 80 per cent of the run-off of streams in Utah comes from areas above 7,000 feet elevation. This area comprises only about 20 per cent of the area of the State. It is the least known area, and yet it holds the key to the State's most valuable resource.

There is a general lack of reliable data on precipitation and other meteorological data on high watersheds in spite of the fact that these areas are the source of water supply for irrigation, domestic, and power purposes. More complete data on mountain watersheds would permit of a more complete utilization of the water resources. Such data on the high and uninhabitated watersheds can be obtained only by snow surveys at the end of the precipitation season.

## PRECIPITATION

*Cause of precipitation.*—All waters which occur above the ocean level result from, and are renewed by, precipitation in some form. Therefore, of necessity, water supplies must vary in amount as the precipitation varies. It is true that there are many modifying factors which influence the yield from a given precipitation, but precipitation is by far the most important single factor.

Condensation of moisture out of the atmosphere may occur as fog, clouds, frost, dew, rain, snow, sleet, or hail. Of these, rain or snow are by far the most important, and the term "precipitation" ordinarily means rain or snow.

Precipitation is caused by what is known as "dynamic cooling," i. e., cooling resulting from the consumption of heat in the work of expansion of rising vapor.[3]

There are three types of precipitation: (1) Convective, (2) orographic, and (3) cyclonic. Convective precipitation is caused by the expanding air in rising vertical air currents which results in dynamic cooling and condensation. Orographic precipitation is brought about by warm air striking a mountain side and being forced to rise. As the air rises it expands, resulting in dynamic cooling and precipitation. Cyclonic precipitation results from the movement of centers of high and low air pressures. The unequal heating of the earth's surface causes the formation of these pressure centers. Warm air is rising in a low pressure area, resulting in precipitation, while cold air falling in a high pressure area results in cooler weather. These pressure centers follow each other across the country from West to East and determine largely the weather during the winter months. The storms usually enter the United States on the coast of Northern California, Oregon, or Washington, and move eastward, bending southward until the continental divide is crossed, and then bending northward again and going out through the St. Lawrence River Valley.

The distance these cyclonic storms paths are deflected southward largely determines the weather and amount of precipitation that falls in Utah during the winter months. The summer precipitation in Utah results principally from local storms. The warm air on hot summer afternoons upon striking the high mountains is forced to rise. As the air rises it expands and cools rapidly causing condensation and precipitation. This type of storm explains the spotted character of the intense summer storms, so common in Utah.

*Distribution of precipitation.*—The climate of Utah is divided into a distinct wet and a distinct dry season. Precipitation is light during June, July, and August and heavier during the remaining months of the year. Approximately 56 per cent of the annual precipitation at Logan occurs during the period October to March, inclusive. Cyclonic storms are the source of most of the precipitation from October to June, inclusive, while local storms furnish the precipitation from July to September, inclusive. The July–September, inclusive, precipitation is approximately 16 per cent of the annual precipitation.

In general, precipitation increases with altitude. There are a few instances, however, where it has been definitely proved that after a certain elevation has been reached precipitation decreases with increased elevation.[4]

*Precipitation.*—There are few precipitation records in Utah available above 7,000 feet elevation. There are some records of summer precipitation at high elevations but no records of winter precipitation.

[1] Contribution from department of irrigation and drainage engineering, Utah Agricultural Experiment Station.

[2] Associate irrigation engineer (also associate member, American Society Civil Engineers). Publication authorized by director, Feb. 6, 1931.

[3] Meyer, A. F. Hydrology (Dynamic Cooling), p. 61, 1928. John Wiley & Sons, New York.

[4] Lee, C. H. U. S. Geol. Surv. Water-Supply Paper 294. Water Resources of Owens Valley, p. 29, pl. 8 (1912).

In Cache Valley since 1923, 18 precipitation stations have been maintained below 5,000 feet, five precipitation stations above 8,000 feet elevation, and one at 6,250 feet elevation. At the high stations, summer precipitation was measured in standard rain gages, but winter precipitation was obtained by measuring the total accumulated snow cover at the end of the winter precipitation season. These records are brought together in this paper to point out the differences in valley and mountain precipitation during summer and winter.

### PHYSICAL FEATURES OF CACHE VALLEY

Cache Valley lies in the northern part of Utah. In shape it is an irregular oval, with its long axis north and south. The maximum width, about 19.5 miles, is attained at the Utah-Idaho boundary. From this point the valley narrows at both the north and the south. About two-thirds of the valley lies in Utah and the remaining one-third in Idaho. The valley area in Utah contains approximately 450 square miles.

Cache Valley is a subsidiary valley formerly occupied by Lake Bonneville. The valley is surrounded on all sides by high, rugged, deeply furrowed mountains which are spurs of the Wasatch Range. The mountains on the east side are higher and cover a greater area than do those on the west. Mount Naomi on the east side reaches an elevation of 9,980 feet while Wellsville Peak on the west reaches an elevation of 9,450 feet. The mountains on the east side of the valley comprise the catchment basin for the streams which enter from that side. The drainage area on the east side is approximately 935 square miles, while that on the west side is only 122 square miles.

Except for Wellsville and Clarkston Peaks, a small low range of mountains on the west side separates Cache Valley from Great Salt Lake Valley. The average elevation of Cache Valley is approximately 4,400 feet, and the average elevation of the watersheds contributing to the valley is approximately 7,000 feet.

The floor of the valley is a broad, slightly undulating plain, gradually sloping up to the foothills of the near-by mountains. The foothills and lower mountain slopes are marked by numerous old lake terraces and deltas, varying in width from a few rods to more than a mile. The generally uniform valley topography is broken by Newton and Smithfield Buttes and by the large irregular fan-shaped terraces extending out from the mouths of the large canyons.

The mountains on the east side of the valley are extremely rugged, with their major axis in a north-south direction. On the west side the axis of the range is also in a north-south direction, and, except for Wellsville and Clarkston Peaks the range is low and rolling. The valley is open from the north. A low range obstructs the valley from the west.

### VALLEY PRECIPITATION

In general, summer storms approach the valley from the south or southwest, while winter storms approach from the north or northwest.

Figure 1 is a map of Cache Valley south of the Utah-Idaho line, including the contributary drainage area. The hatched line shows the approximate location of the foot of the mountain slopes. Within this designated line is the valley proper. The valley precipitation stations are marked by open circles and the mountain stations by solid circles.

Precipitation on the valley floor varies widely, the heavier precipitation occurring along the foothills. Iso-

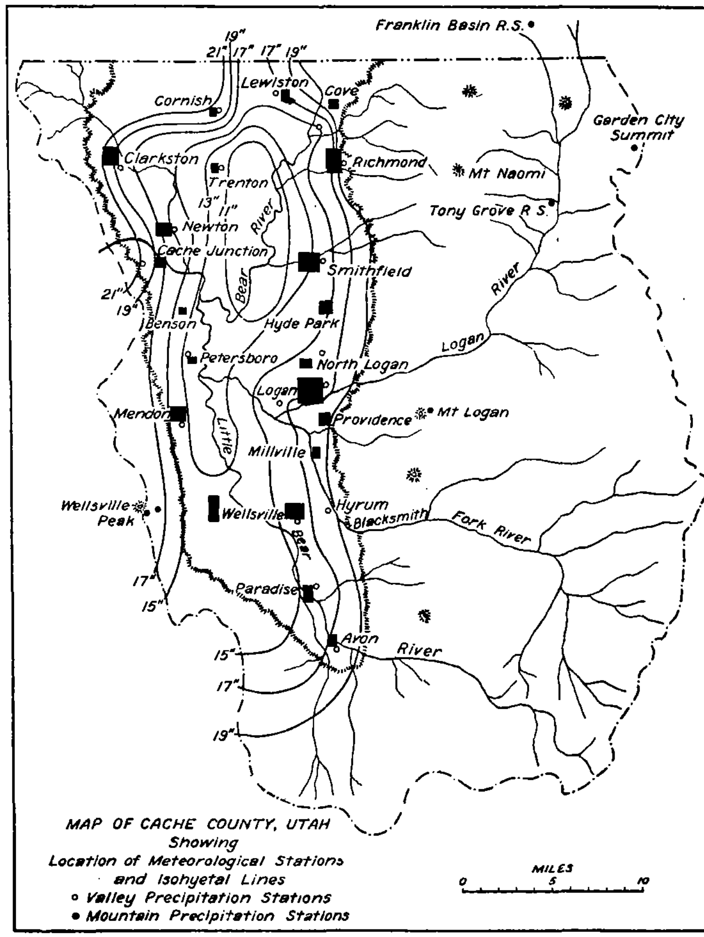


FIGURE 1

hyetal lines, indicated on Figure 1, show the general distribution of the precipitation over the valley floor. The mean annual precipitation on the valley floor varies from 11 to 21 inches. The isohyetal lines show the least annual precipitation to be over the lowest portion of the valley floor and the greatest near the foothills. The precipitation seems to increase quite uniformly with the elevation from the valley floor to the foothills. From the foothills to the top of the mountains, the precipitation increases, but the rate of increase varies widely from year to year.

TABLE 1.—*Showing mean monthly, mean seasonal, and mean annual precipitation in Cache County, Utah*

| Meteorological station | January | February | March | April | May | June | July | August | September | October | November | December | April to June, inclusive | July to September, inclusive | October to March, inclusive | Mean annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Greenville | 1.44 | 1.34 | 2.00 | 2.62 | 1.43 | 0.94 | 0.44 | 0.63 | 1.06 | 1.34 | 1.17 | 1.91 | 4.99 | 2.13 | 9.20 | 16.32 |
| Avon | 1.56 | 1.86 | 2.70 | 2.09 | 1.44 | 1.43 | .75 | .73 | 1.40 | 1.52 | 2.00 | 1.96 | 4.96 | 2.88 | 11.60 | 19.44 |
| Paradise | 1.20 | 1.96 | 1.27 | 2.15 | 2.00 | .23 | 1.75 | .73 | 1.66 | 1.79 | 1.54 | 1.80 | 4.38 | 4.14 | 9.56 | 18.08 |
| Hyrum U. P. & L | .93 | 1.75 | 1.91 | 2.50 | 1.93 | .86 | .56 | .73 | 1.57 | 1.69 | 1.85 | 2.54 | 5.29 | 2.86 | 10.67 | 18.82 |
| Hyrum, A. Fallows | .53 | 1.55 | 1.95 | 1.61 | 1.43 | .79 | 1.26 | .81 | 1.20 | 1.34 | 1.42 | 1.81 | 3.83 | 3.27 | 8.60 | 15.70 |
| Logan sugar factory | 1.90 | 1.46 | 2.35 | 2.17 | 1.46 | 1.03 | .37 | .39 | 1.36 | 1.80 | 1.59 | 1.08 | 4.66 | 2.12 | 10.18 | 16.96 |
| Logan, U. S. A. C | 1.16 | 1.29 | 1.70 | 1.75 | 1.50 | 1.11 | .59 | .56 | 1.60 | 1.23 | 1.32 | 1.36 | 4.36 | 2.75 | 8.06 | 15.17 |
| Petersboro | .94 | 1.33 | 1.83 | 1.70 | 1.45 | .85 | .56 | .47 | 1.22 | 1.23 | 1.23 | 1.17 | 4.00 | 2.25 | 7.73 | 13.98 |
| Smithfield (near) | 1.10 | 1.68 | 1.83 | 1.92 | 1.83 | 1.07 | .87 | .59 | 1.57 | 1.76 | 1.19 | .74 | 4.82 | 3.03 | 8.30 | 16.15 |
| Cache Junction | 1.30 | 2.12 | 1.95 | .98 | 2.41 | .71 | 1.71 | 1.21 | 1.26 | 1.92 | 1.81 | 2.04 | 4.10 | 4.18 | 11.14 | 19.42 |
| Newton | .92 | 1.43 | 1.60 | 1.46 | 2.07 | .97 | .73 | .63 | 1.23 | 1.58 | 1.53 | 1.30 | 4.50 | 2.59 | 8.36 | 15.45 |
| Trenton | .90 | .40 | 1.45 | .50 | .81 | 1.25 | .51 | .66 | 1.23 | 1.64 | .45 | | 2.56 | 2.40 | 4.84 | 9.80 |
| Clarkston | .80 | .50 | 1.56 | 1.88 | 2.14 | 1.17 | 1.15 | .71 | 1.54 | 1.87 | 1.98 | 1.10 | 5.19 | 3.40 | 7.81 | 16.40 |
| Cornish | .75 | .84 | 2.61 | .99 | 1.17 | 1.20 | 1.56 | 1.33 | .91 | 1.78 | .90 | 2.12 | 3.36 | 3.80 | 9.00 | 16.16 |
| Lewiston, 1 | .96 | 1.09 | 2.03 | 1.21 | 1.60 | 1.49 | 1.05 | .55 | 1.24 | 1.57 | 1.76 | 1.36 | 4.30 | 2.84 | 8.77 | 15.91 |
| Lewiston, 2 | 1.37 | 1.36 | 2.00 | 2.02 | 1.78 | 1.53 | .86 | .69 | 1.65 | 1.54 | 2.02 | 1.15 | 5.33 | 3.20 | 9.44 | 17.97 |
| Richmond, 1 | .77 | 2.15 | 1.67 | 1.97 | 1.72 | .96 | .94 | .84 | 1.64 | 1.17 | 1.99 | 1.78 | 4.65 | 3.42 | 9.53 | 17.60 |
| Richmond, 2 | 1.28 | 1.21 | 2.30 | 1.99 | 1.54 | 1.01 | .77 | .73 | 1.54 | 1.55 | 1.63 | 1.73 | 4.54 | 3.04 | 9.70 | 17.28 |

Table 1 gives the mean monthly, mean seasonal, and mean annual precipitation at each of the 18 valley stations. It will be noted that the maximum annual precipitation occurred at Avon, a foothill station, and the minimum at Trenton, a station in the bottom of the valley. Every month shows a variation between stations, but the widest variations seems to occur during June, July, and August.

The average annual precipitation for 18 stations is approximately 8.5 per cent greater than that recorded at the United States Weather Bureau station at Logan. The average valley precipitation at the 18 stations from April to June, inclusive, equals 4.43 inches, or 27 per cent of the average annual precipitation. The average precipitation July to September, inclusive, equals 3.02 inches, or 18.3 per cent. This relatively high spring and summer precipitation accounts largely for the successful dry farms on the foothills surrounding Cache Valley.

## MOUNTAIN PRECIPITATION

*Summer precipitation.*—Cyclonic storms are the source of most of the precipitation in Cache Valley; these storms occur with the greatest frequency during the winter and early spring. The local storms furnish most of the summer precipitation. These storms occur irregularly and are extremely spotted in intensity and total amount. They apparently contribute little to the stream flow but are important in the production of range vegetation and dry-farm crops.

In 1924 several rain gages were installed on the Logan watershed at points above 8,000 feet elevation to determine the amount of summer precipitation. These gages were set up as soon as the temperatures would permit in the spring and were taken down in the fall when the snow started to accumulate on the ground. A comparison of the record at these mountain stations with the corresponding record at the United States Weather Bureau station at Logan reveals some interesting relationships. The record at the mountain stations is compared with the record for the corresponding days at the valley station. Table 2 shows the stations compared, the elevation of each station, the period of record, and the precipitation at each station in inches. Only two stations were in operation in 1924. Franklin Basin station was not started until September 1, 1924, and, therefore, is not strictly comparable. The precipitation at 9,000 feet elevation for that year (1924) was only 9 per cent greater than the valley precipitation during the period from June 27 to September 18, inclusive. At Franklin Basin (elevation, 8,200 feet) less than one-half as much rain fell as at the Logan station (elevation, 4,780 feet) during the period from September 1 to October 31, inclusive.

During the summer of 1925 the precipitation above 8,000 feet elevation was constantly higher than in the valley. At Franklin Basin it was over three times as much, and at Wellsville Peak (elevation, 8,300 feet) it was nearly twice as much. The average of all mountain stations shows the valley precipitation to be only 54.8 per cent of the mountain precipitation. This record shows the spotted character of the mountain precipitation.

Conditions were entirely different during the summer of 1926. The valley precipitation exceeded the mountain precipitation at Mount Logan and Wellsville Peak (upper), while it was less than the mountain precipitation at Wellsville Peak (lower) and Franklin Basin. The valley precipitation for 1926 averaged 104.3 per cent of the mountain precipitation. The record for 1926 also shows the spotted character of the mountain precipitation.

TABLE 2.—*Comparison of precipitation on high watershed with that of valley, U. S. A. C., Logan*

| No. | Elevation | Station | Year 1924 period | Precipitation | Valley precipitation (U. S. A. C., Logan) | Year 1925 period | Precipitation | Valley precipitation (Logan) |
|---|---|---|---|---|---|---|---|---|
| 1 | 6,250 | Tony Grove R.S. | | | | 7/19–10/16 | 3.10 | 4.03 |
| 2 | 9,000 | Mount Logan | 6/27–9/18 | 1.33 | 1.22 | 7/16–10/21 | 6.25 | 4.03 |
| 3 | 8,200 | Franklin Basin | 9/1–10/31 | 1.22 | 2.76 | 5/15–10/3 | 19.85 | 6.40 |
| 4 | 9,400 | Wellsville Peak | | | | 7/20–9/25 | 5.35 | 3.50 |
| 5 | 8,300 | do | | | | 5/25–9/25 | 11.03 | 6.00 |
| 6 | 4,778 | U. S. A. C., Logan | 5/1–9/30 | 2.49 | 2.49 | 5/1–9/30 | 7.20 | 7.20 |
| 7 | 7,600 | Summit G. C. | | | | | | |

| No. | Elevation | Station | Year 1926 period | Precipitation | Valley precipitation (Logan) | Year 1927 period | Precipitation | Valley precipitation (Logan) |
|---|---|---|---|---|---|---|---|---|
| 1 | 6,250 | Tony Grove R.S. | | | | 6/1–10/4 | 4.74 | 3.99 |
| 2 | 9,000 | Mount Logan | 5/27–10/30 | 3.95 | 5.23 | 6/28–10/15 | 5.17 | 3.80 |
| 3 | 8,200 | Franklin Basin | 4/10–8/1 | 5.00 | 4.15 | | | |
| 4 | 9,400 | Wellsville Peak | 6/1–10/16 | 4.13 | 5.12 | 6/21–10/11 | 2.72 | 3.80 |
| 5 | 8,300 | do | 6/1–10/16 | 6.53 | 5.12 | 6/21–10/11 | 3.94 | 3.80 |
| 6 | 4,778 | U. S. A. C., Logan | 5/1–9/30 | 7.03 | 7.03 | 5/1–9/30 | 6.45 | 6.45 |
| 7 | 7,600 | Summit G. C. | | | | 7/2–10/4 | 5.15 | 3.61 |

TABLE 2.—*Comparison of precipitation on high watershed with that of valley, U. S. A. C., Logan*—Continued

| No. | Elevation | Station | Year 1928 period | Precipitation | Valley precipitation (Logan) | Year 1929 period | Precipitation | Valley precipitation (Logan) |
|---|---|---|---|---|---|---|---|---|
| 1 | 6,250 | Tony Grove R.S. | | | | 7/10– 9/24 | 3.05 | 3.35 |
| 2 | 9,000 | Mount Logan | 6/1 –10/29 | 2.33 | 3.00 | 6/1 –10/18 | 5.40 | 5.93 |
| 3 | 8,200 | Franklin Basin | | | | 7/10– 9/24 | 2.67 | 3.35 |
| 4 | 9,400 | Wellsville Peak | 6/1 – 9/15 | .80 | 1.88 | 6/27–10/12 | 4.60 | 4.47 |
| 5 | 8,300 | do | 6/1 – 9/15 | 2.40 | 1.88 | 6/27–10/12 | 4.00 | 4.47 |
| 6 | 4,778 | U. S. A. C., Logan | 5/1 – 9/30 | 3.35 | 3.35 | 5/1 – 9/30 | 5.22 | 5.22 |
| 7 | 7,600 | Summit G. C | | | | 6/13– 9/24 | 3.95 | 4.76 |

| No. | Elevation | Station | Year 1930 period | Precipitation | Valley precipitation (Logan) |
|---|---|---|---|---|---|
| 1 | 6,250 | Tony Grove R.S. | 6/7 –10/7 | 6.48 | 5.89 |
| 2 | 9,000 | Mount Logan | 6/22– 9/27 | 5.55 | 4.90 |
| 3 | 8,200 | Franklin Basin | 6/15–10/7 | 5.79 | 5.89 |
| 4 | 9,400 | Wellsville Peak | 6/7 – 9/28 | 8.50 | 5.30 |
| 5 | 8,300 | do | 6/7 – 9/28 | 7.73 | 5.30 |
| 6 | 4,778 | U. S. A. C., Logan | 5/1 – 9/30 | 8.45 | 8.45 |
| 7 | 7,600 | Summit G. C | 6/7 – 9/9 | 4.58 | 3.82 |

NOTE.—An oil film was used in the mountain gages to prevent evaporation. The gage was emptied near the first of each month.

In 1927 the mountain precipitation was spotted and the valley precipitation was only 95 per cent of the average mountain precipitation. The mountain precipitation was spotted in 1928, but during this season the valley precipitation exceeded the average of the mountain stations.

Precipitation on the high areas during the summer of 1929 was extremely spotted. At every station except Wellsville Peak (upper) the valley precipitation exceeded that on the mountains. The valley precipitation for 1929 was 113 per cent of the average on the mountains.

The season of 1930, which was marked by several torrential storms during the months of July and August, shows a more uniform distribution of precipitation and a heavier total than any of the previous years of record, except for 1925. The mountain precipitation for the summer of 1930 was considerably heavier than the valley precipitation, the latter being only 81 per cent of the average mountain precipitation.

Although only records for seven years are available, it is quite evident that (1) there is no fixed relationship between the valley and the mountain precipitation and (2) that the mountain precipitation is extremely spotted in character. These records show that the mountain precipitation during the summer season does not greatly exceed the valley precipitation; in fact, during some years the precipitation in the valley exceeds that on the mountains. Valley precipitation stations in this regard are not good indicators of precipitation on high-mountain watersheds during the summer. Due to the spotted character of summer precipitation on mountain watersheds, a large number of precipitation stations are necessary to obtain an average record of precipitation for any given area.

*Winter precipitation.*—Precipitation and temperature records at Logan and observations made on the Logan River watershed show that at elevations above 8,000 feet most of the precipitation occurs as snow after November 1, and that it accumulates from that date until after the following April 1, when the melting season usually starts. Based on the assumption that any precipitation which occurs on the watershed above 8,000 feet elevation after November 1 accumulates on the ground, a measurement of the water content of the snow cover at the end of the precipitation season and before melting begins should give approximately the total precipitation occurring between these dates.

On the Logan River watershed snow surveys have been made for seven years on three courses. These courses are all above 8,000 feet elevation and are about 15 miles apart. They have proved to be representative of the snow cover conditions above 8,000 feet over the entire area.

To make a comparison between the winter precipitation on high watersheds and valley precipitation, the valley precipitation at Logan was computed for the period, November 1 to the date of the annual snow survey. The total precipitation for this period was then compared with the water content of the snow cover on the date of the survey.

Table 3 gives the precipitation at Logan (elevation 4,780 feet) and the average water equivalent of the snow cover for the three courses above 8,000 feet elevation. The snow cover measurements represent the mean of 106 annual observations taken 100 feet apart at fixed points so that the snow cover was measured in exactly the same way each year. A comparison of precipitation, caught in a standard rain gage with accumulated snow cover, is subject to some errors due to evaporation of snow and also due to snow on the ground prior to November 1 or to melting of snow after November 1. Field observations at the beginning of the accumulation season and of the soil under the snow at the time of the snow survey apparently indicates the error from these two to be slight.

TABLE 3.—*Comparison of winter precipitation above 8,000 feet and below 5,000 feet, Logan River watershed*

| Year | Period | Precipitation at Logan (inches), elevation, 4,780 | Water equivalent in inches of snow cover accumulated during period given | | | | Mountain precipitation in percentage of valley precipitation |
|---|---|---|---|---|---|---|---|
| | | | Franklin Basin, elevation, 8,200 | Tony Grove Lake, elevation, 8,300 | Mount Logan, elevation, 9,000 | Mean | |
| 1923–24 | Nov. 1–Apr. 6 | 4.69 | 25.1 | 31.8 | 25.8 | 27.6 | 590 |
| 1924–25 | do | 7.79 | 28.3 | 35.5 | 32.1 | 31.96 | 410 |
| 1925–26 | Nov. 1–Apr. 8 | 8.42 | 18.4 | 21.9 | 22.0 | 20.76 | 226 |
| 1926–27 | Nov. 1–Apr. 6 | 9.53 | 33.8 | 43.5 | 40.8 | 39.30 | 413 |
| 1927–28 | Nov. 1–Apr. 5 | 6.23 | 31.7 | 34.9 | 31.6 | 32.70 | 524 |
| 1928–29 | Nov. 1–Apr. 3 | 6.79 | 31.1 | 36.5 | 35.0 | 34.20 | 503 |
| 1929–30 | Nov. 1–Mar. 30 | 6.54 | 26.8 | 31.5 | 25.9 | 28.06 | 507 |
| 7-year mean | | 7.14 | 27.88 | 33.05 | 30.45 | 30.65 | 430 |

The few records available show that evaporation from snow cover between November 1 and April 1 is slight. The record for the period from 1923–24 to 1929–30, inclusive, shows that the average precipitation above 8,000 feet was 4.3 times the precipitation for the same period at the United States Weather Bureau station at Logan. The winter precipitation above 8,000 feet varied from 2.3 times the valley precipitation during the extremely low-water year in 1926 to 5.9 times during 1923–24.

There seems to be no relationship between the valley and mountain precipitation. The maximum valley precipitation came the same year as the maximum mountain precipitation; the second highest valley precipitation (9.53 inches against 8.42 inches) came during the same year as did the minimum mountain precipitation. Figure 2 shows the poor correlation between valley and mountain winter precipitation in northern Utah.

The minimum discharge of Logan River from 1923–24 to 1929–30, inclusive, occurred in 1926. This was year of minimum precipitation above 8,000 feet elevation; it was also a year of above-normal valley precipitation. The maximum discharge occurred in 1927, which was a year of maximum precipitation both in the valley and on the mountains. The average annual discharge of Logan River is 221,645 acre-feet, or a uniform depth over the watershed of 19 inches. This is more by 2.5 inches than the annual precipitation at Logan, a valley station. On many Utah watersheds the run-off depth is greater than the valley precipitation on these watersheds.

| Year | Period | Precip. at Logan Elev 4780 | Mountain Precip Above 8000 Feet Elevation | Valley Precip. in Percentage of Mountain Precip. |
|---|---|---|---|---|
| 1923–24 | Nov 1–Apr. 6 | 4.69 | 27.6 | 17.0 |
| 1924–25 | Nov 1–Apr. 6 | 7.79 | 31.9 | 24.4 |
| 1925–26 | Nov. 1–Apr 8 | 8.42 | 20.7 | 406 |
| 1926–27 | Nov. 1–Apr. 6 | 9.53 | 39.3 | 24.2 |
| 1927–28 | Nov. 1–Apr. 5 | 6.23 | 32.7 | 19.4 |
| 1928–29 | Nov. 1–Apr. 3 | 6.79 | 34.2 | 20.2 |
| 1929–30 | Nov. 1–Apr. 1 | 6.54 | 28.1 | 23.2 |

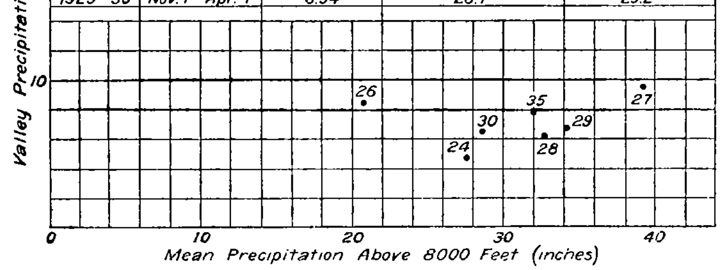


FIGURE 2

The record cited in Figure 2 shows little, if any, relationship between valley and mountain precipitation in northern Utah. This means that precipitation occurring in the valley is a poor index of the precipitation on the high watersheds or of the water-supply to be derived therefrom.

Figure 3 shows the winter valley precipitation and the winter mountain precipitation plotted against the run-off for April to September, inclusive. These curves show a poor relationship between valley precipitation and run-off. The relationship between winter mountain precipitation and run-off is much closer. Although the available record of winter precipitation on high watersheds is short, the winter precipitation as measured by annual snow surveys apparently is a good index of the water supply to be expected from such watersheds.

SUMMARY

1. Precipitation on the valley floor of Cache Valley varies widely, increasing with elevation from the bottom of the valley floor to the foothills.
2. The average spring and summer precipitation for the 18 valley stations equaled approximately 45 per cent of the total annual precipitation.
3. The summer precipitation at the valley stations is spotted, while the winter precipitation is more uniform.
4. Summer precipitation above 8,000 feet is extremely spotted.

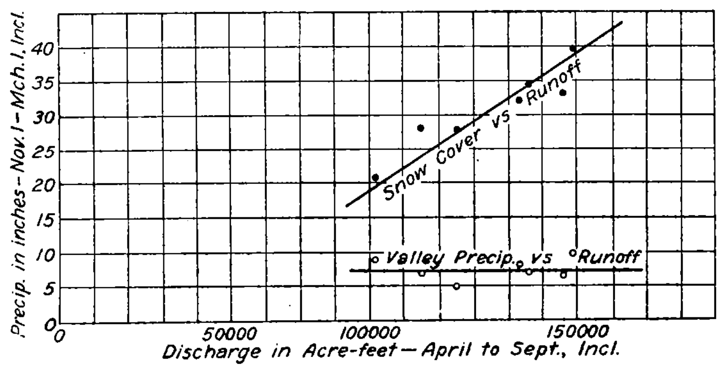


FIGURE 3

5. There seems to be no fixed relationship between the valley and mountain precipitation during the summer season.
6. Winter precipitation on high mountain watersheds is measured by snow surveys. It is quite uniform over wide areas.
7. The water equivalent of the accumulated snow cover on high watersheds is several times the valley precipitation during the period of accumulation.
8. Existing records indicate that during the winter season for northern Utah watersheds there is no relationship between valley and mountain precipitation.
9. Valley precipitation is a poor index of the probable water supplies and at times may be misleading.
10. Mountain precipitation measured above 8,000 feet elevation seems to be a good index of stream flow from that area.

# THE GREEN FLASH OBSERVED OCTOBER 16, 1929, AT LITTLE AMERICA BY MEMBERS OF THE BYRD ANTARCTIC EXPEDITION

By WILLIAM C. HAINES

[Weather Bureau, Washington, D. C.]

On the evening of October 16, 1929, between 8:45 p. m. and 9:20 p. m. (180 meridian time), several members of the expedition observed a very striking example of the green flash. At the time the sun was skirting the southern horizon, its disk disappearing at intervals only to reappear again a few moments later. This fluctuation was caused by the unevenness of the barrier surface which formed the line of the horizon. The irregularities in the snow surface permitted the upper limb of the sun to appear in one or more starlike points of light from adjacent notches. These points or flares of light would sometimes have a greenish color on their appearance or disappearance. The length of time during which the green flare was visible varied from a fraction of a second to several seconds, and at times it was possible to keep it in view or to make it reappear again by raising or lowering the head. Occasionally green, orange, and red flares could be seen simultaneously at different points, giving one the impression of traffic lights. When the sun sank too low to be seen from the ground, it was still visible from elevated points such as the anemometer post or radio towers. The above effect was seen at intervals during a period lasting over half an hour.

At the time of occurrence of the phenomenon the sky was seven-tenths covered with clouds, the clear portion being along the southern horizon. A few patches of alto-stratus clouds in the vicinity of the sun showed sunset colors. There was a light southerly wind (8 miles an hour) and the temperature was −24° F. at the time. Between the sun and the camp lay a depression in the barrier within which the air was often much colder and less disturbed